10/580215
IAP20 Rec'd PCT/PTO 23 MAY 2006

DYNAMIC STABILISER FOR A BOAT EQUIPPED WITH STABILISATION AND BOAT THUS OBTAINED

The technical scope of the present invention is that of boats, and more particularly boats comprising drag reduction and/or stabilising devices.

In the nautical domain, hydrodynamic drag is sought to be reduced so as to make boats quicker thereby reducing their fuel consumption.

This reduction in drag may be obtained by reducing the support surface on the water. To reduce this surface, vessels with submerged float are known or boats which use the principle of foils, such boats namely being known as hydrofoils.

Thus, patent US-4 993 348 describes a boat comprising a submerged float. Its submerged stabilising device however suffers the drawback of having its range limited by hydrodynamic drag, thereby reducing its effectiveness.

Patent US-6 578 507 describes a boat comprising arms fitted at their ends with foils enabling the boat, when navigating at high speed, to be borne only by its foils. Such a device suffers the drawback, however, of having no stability regarding pitch and roll and does not enable the trim to be kept stable when navigating into waves.

The purpose of the invention is to overcome the drawbacks of currently known devices by proposing a boat that simultaneously offers low hydrodynamic drag and stabilisation of the boat with respect to the waves when navigating at high speed. This stabilisation concerns all the five parasitic components of roll, pitch, yaw, as well as the alternative movements of the centre of gravity of the boat due to the passage of waves, constituted by the vertical movement of the centre of gravity (alternatively up and down) and the lateral movement of the centre of gravity (alternatively offsetting from port to starboard). The invention also aims to regulate the torque to which the sails are subjected when the boat is wind propelled.

The invention thus relates to a hydrodynamic stabiliser for a boat, comprising a submersible strut in the water supporting at its end a first substantially horizontal submerged aileron, mounted able to rotate with respect to the submersible strut according to a horizontal pivot, wherein the first aileron comprises a trailing edge flap jointed to rotate around an axis near to the trailing edge of said aileron and wherein said flap is controlled by a rotational drive mechanism with respect to said aileron so as to orient said aileron.

According to one characteristic of the invention, the stabiliser comprises a second substantially vertical submerged aileron that rotates around the submersible strut and which comprises motor means so as to be oriented.

According to another characteristic of the invention, the stabiliser comprises a second substantially vertical aileron able to rotate freely around the submersible strut and comprising a trailing edge flap jointed to rotate around an axis near to the trailing edge of said second aileron, said flap being controlled by a rotational drive mechanism with respect to the second aileron so as to orient said second aileron.

According to yet another characteristic of the invention, the submersible strut comprises a streamlined fairing able to rotate freely around said submersible strut so as to freely orient itself in the local flow direction of the water.

According to another characteristic of the invention, return means, of the elastic or motor type, are positioned between the submersible strut and the rotating streamlined fairing so as to impose a restoring torque on said fairing when this fairing is angularly offset.

According to another characteristic of the invention, the rotating streamlined fairing comprises a hydrodynamic lift element on its downstream side that is fixed with respect to said fairing or is able to be oriented in vertical rotation with respect to the fairing.

The invention also relates to a stabilisation device for a boat implementing at least one stabiliser, wherein said at least one stabiliser is carried by a substantially horizontal arm integral with the boat, said arm being located above the water.

According to yet another characteristic of the invention, certain arms are made integral with the boat by a pivot type link with several lockable positions so as to make them foldable.

According to another characteristic of the invention, certain arms are constituted by several sections connected together by a pivot type link with several lockable positions so as to make them foldable.

According to another characteristic of the invention, certain submersible struts are integral with an arm by means of a pivot link with a substantially horizontal axis able to be locked in several positions, a lowered position for said submersible struts when the orientable hydrodynamic ailerons are in use and a raised position for said submersible struts when said ailerons are not in use, the boat being immobile or moving at low speed.

According to another characteristic of the invention, the retention of certain submersible struts in the lowered position is ensured by resistance locking calibrated for a force tending to push back said submersible struts, wherein said locking leaves said submersible struts able to rotate backwards and upwards when said limit resistance has been attained.

According to another characteristic of the invention, the stabilisation device comprises a calculator cooperating with static and/or dynamic sensors and piloting the orientation means of the aileron or ailerons so as to vary their orientation according to the movements of said boat.

The invention also relates to a load compensation device to orient the sails of a boat or sailing craft, wherein it firstly comprises, a global elastic device pressing on a fixed part of the boat and comprising an output part able to move on a certain course, or a certain displacement, said

mobile output part transmitting an elastic load whose intensity increases according to the amplitude of its displacement, said global elastic device being constituted by one or several elastic organs positioned between said fixed part of the boat and said mobile output part, the addition of the individual elastic loads of said elastic organs supplying the global elastic load to said mobile output part of said global elastic device, and secondly, a device to transmit the movement of said mobile output part of said global elastic device to said sails, said movement transmission device changing its transmission ratio according to the angle of orientation of said sails such that the elastic restoring torque which it exerts on said sails, tending to bring the mean plane of the latter parallel to the plane of symmetry of the boat, or sail craft, is of constant intensity, or else of slightly and gradually increasing intensity, when said sails pivot from the orientation corresponding to the "close-hauled" point of sailing to that corresponding to the "following wind" point of sailing.

According to another characteristic of the invention, the sail orientation organ is a sheet connected at one end to the sails and winding at the other around a drum integral with or linked in rotation to a drum winch with variable winding radius acting as the movement transmission device.

According to another characteristic of the invention, the global elastic device comprises means to adjust the mean elastic load enabling it to be adapted to the prediction, for a given lapse of time, of the mean orientation load of the sails.

According to another characteristic of the invention, the compensation device comprises means to adjust the sail orientation angle, and said orientation angle adjustment means comprise a manual handling organ.

According to another characteristic of the invention, the compensation device comprises means to adjust the orientation of the sails and said means comprise an actuator controlled by a signal from a calculator or from control means piloted by a member of the crew.

According to another characteristic of the invention, the compensation device comprises bidirectional limitation means for the load, force or torque, communicated by the actuator to the sails.

According to another characteristic of the invention, the global elastic device comprises one or several pneumatic or hydraulic jacks linked by one or more lines to one or more tanks containing compressed gas.

According to another characteristic of the invention, at least one tank is connected by means of a valve to a source of pressure, depression or free air, so as to be able to modify the pressure present in said tank.

According to another characteristic of the invention, certain elastic organs of the global elastic device may be suspended from use when navigating, either by the temporary uncoupling of their own elastic movement output organ with respect to the device to transmit movement to the sails, or by the temporary uncoupling of their base with respect to the boat structure to which said base is usually joined, or by the temporary neutralisation of their elastic properties, then brought back into use when navigating by re-coupling the elastic organs temporarily uncoupled or by re-establishing the elastic properties having been temporarily neutralised.

According to another characteristic of the invention, the movement transmission device comprises at least two drums revolving freely around shafts fixed with respect to the boat structure, coupled in rotation, either directly, or by means of a constant or variable ratio transmission mechanism, drums onto which two opposite winding cables are anchored one of which at least is wound in a groove of variable winding radius, the first cable being linked directly or by means of tackle to the elastic movement output organ of the global elastic device, the second cable being linked directly or by means of tackle to a point of the sails enabling them to be oriented.

According to another characteristic of the invention, the actuator of the compensation device is constituted by, or comprises, a rotating electric stepper motor.

According to another characteristic of the invention, the compensation device comprises a load, force or torque amplifier, comprising at least one streamlined submerged blade with hydrodynamic lift, which may be oriented around a pivot parallel to its longitudinal axis, this pivot being mobile transversally to the current due to the displacement of the boat.

According to another characteristic of the invention, the actuator of the compensation device is controlled by a calculator linked to sensors enabling the orientation of the wind direction and the sails to be measured with respect to the boat.

According to another characteristic of the invention, substantially vertical stanchions integral with the boat, surrounded by freely-turning cylindrical sleeves, are provided to intercept the passage of the sheet or sheets when they reach the fore part of the boat so as to reduce stressing on the global elastic device.

The invention also relates to a boat comprising a platform, at least one main, completely submerged, streamlined float, integral with the platform by one or more supporting pylons which take up the full weight of the platform to keep it out of the water, wherein it comprises arms radiating out from the platform, which are substantially horizontal and which support submersible struts extending into the water, fitted with submerged orientable ailerons with hydrodynamic lift effect, said arms being located above the water, mobile streamlined fairings, freely rotating under the effect of the local current and individually enveloping each supporting pylon, at least three auxiliary closed-hull floats, watertight and streamlined, spaced around the platform to ensure balanced trim when immobile or at low speed, integral with the radiating arms or with the platform.

According to another characteristic of the invention, the boat comprises a stabilisation device, provided by said radiating arms, said submersible struts, and said orientable ailerons.

According to another characteristic of the invention, the boat comprises an adjustable preload device enabling the boat's mass to be increased or decreased by means of ballasts with adjustable water intake.

According to another characteristic of the invention, the submersible struts extending into the water as well as certain auxiliary floats are positioned near to the ends of radiating arms.

According to another characteristic of the invention, at least one auxiliary float is fixed to a radiating arm by a link having several lockable positions thereby enabling this float to be brought closer to the platform when the craft is stopped or by a pivot type link with a substantially vertical hinge pin having several lockable positions.

According to another characteristic of the invention, the boat comprises means to measure the position, inclination, speed and/or acceleration, cooperating with a calculator so as to determine the movements of the boat and to model these movements as roll, pitch, yaw movements and/or alternating movements of the boat's centre of gravity due to the passage of the waves, constituted by the vertical movement of the centre of gravity (alternatively up and down) and the lateral movement of the centre of gravity (alternatively offsetting from port to starboard).

According to another characteristic of the invention, the boat comprises measurement means, such as anemovanes, sail orientation sensors, submerged vanes, pressure sensors, surface reflection sonars, surface probes, video cameras, or any other means cooperating with the calculator so as to determine the wave movement upstream of each main submerged float, to model the movements of the water transversal to the path of the boat along the axis of each of said floats, these movements being broken down, for example, along two non parallel transversal axes, or to determine the aerodynamic forces on those boat elements offering wind resistance.

According to another characteristic of the invention, the calculator cooperates with the orientation means for the orientable ailerons so as to orient them according to the

simulation of the boat's movements and/or the wave movements and/or the aerodynamic forces, to thereby provide stabilisation for the boat by controlling its trim and trajectory.

According to another characteristic of the invention, certain orientable ailerons comprise an angular sensor which measures the angle of rotation of the ailerons with respect to the submersible strut and cooperates with the calculator.

According to another characteristic of the invention, the boat comprises a balancing device with mobile masses permanently-adjustable by the lateral and/or longitudinal displacements of mobile counterweights along guides, positioned along such guides by mechanisms comprising actuators, or comprising a mass of water that can be transferred between distanced tanks, said balancing device cooperating with the calculator so as to modify the position of the boat's centre of gravity according to its movements and to the unbalancing effects due, for example, to the distribution of the payload or to the wind.

According to another characteristic of the invention, the balancing device comprises tanks located in the auxiliary floats and partly filled with water, said tanks being connected together by piping and at least one pump cooperating with the calculator so as to distribute the water among the tanks.

According to another characteristic of the invention, each supporting pylon located between a fully submerged main streamlined float and the platform is retractable, with several lockable positions, as well as the rotating fairing surrounding it, in a housing in said platform.

According to another characteristic of the invention, the boat comprises wind propulsion means and the orientation of at least one wind propulsion means is ensured by a load compensation device to orient sails.

A first advantage of the boat according to the invention lies in the fact that as from a certain speed and in waves of a depth less than the height of its rotating fairings it is not affected by the effects of roll, pitch, yaw, transversal

sway (either upward/downwards or port/starboard). This advantage comes from the combination of the fully submerged main streamlined float(s) (with constant Archimedes' thrust), from the characteristics of the elements breaking the surface (small section and incidence on the Archimedes' thrust, streamlining and rotating vane minimise the effects of transversal waves), from the long radiating arms (wide lever arm contributing to the lift of the submerged orientable ailerons) and the orientation of the ailerons which oscillate with the waves (incidence and lift remaining proportional to the stabilisation load setting given, despite the wave passage).

Another advantage lies in the fact that the hydrodynamic drag is extremely reduced, thereby enabling the boat to reach high speeds.

Another advantage lies in the facility of access to shallow waters thanks to the reduced draught enabled by lifting the submerged main streamlined float(s) and by lifting the submersible struts, as well as in the facility of berthing in harbours thanks to the reduced horizontal encumbrance enabled by the foldable radiating arms.

Other characteristics, particulars and advantages of the invention will become more apparent from the following description given hereafter by way of illustration and in reference to the drawings, in which:

- Figure 1 shows a hydrodynamic stabiliser according to a first embodiment of the invention,
- Figure 2 shows a hydrodynamic stabiliser according to another embodiment of the invention,
- Figure 3 shows a hydrodynamic stabiliser according to another embodiment of the invention,
- Figures 4a to 4d show embodiments of rotating fairings according to the invention,
- Figures 5 and 6 show an example of the application of a stabilisation device according to the invention to a pleasure boat,

- Figure 7 shows another example of the application of the stabilisation device according to the invention to a multi-hull boat,

- Figure 8 shows an embodiment of the submersible strut head safety hinge according to the invention,

- Figure 9 shows a boat with a submerged float according to the invention,

- Figure 10 shows a specific arrangement of an arm according to the invention,

- Figures 11a and 11b shows the functioning of an embodiment of the adjustable preload device,

- Figure 12 shows an embodiment of the balancing device with permanently-adjustable mobile masses,

- Figure 13 is a schematic view showing a specific embodiment of an arm according to the invention,

- Figure 14a shows an example of a sailing boat equipped with several load regulation devices according to the invention,

- Figure 14b is a functional schematic drawing of a device according to the invention,

- Figures 15 and 16 show an example of a pneumatic jack and its tank from the load-regulation device according to the invention, and

- Figure 17 shows an example of a variable radius cable winding drum from the load-regulation device according to the invention.

Figure 1 shows a first embodiment of a hydrodynamic stabiliser 15 for a boat according to the invention. In this embodiment, the stabiliser 15 comprises a vertical submersible strut 5 integral with the boat structure, a streamlined fairing 6 and a first substantially horizontal orientable hydrodynamic aileron 1. The streamlined fairing 6 is free to rotate around said submersible strut 5 so as to spontaneously orient itself in the direction of the local water flow. The orientable hydrodynamic aileron 1 rotates freely around a horizontal hinge pin 3, with an axis 10, arranged at the end of the submersible strut 5. The orientable aileron 1 comprises a trailing edge flap 7 hinged

around a hinge pin 21 near to the trailing edge of the aileron. The rotation of the trailing edge flap 7 with respect to the aileron is controlled by a drive mechanism of a known type (not shown), for example a watertight electric motor.

The stabiliser functions as follows:

During the displacement of the boat, the aileron 1 spontaneously orients itself under the effect of the opposing torques due to its own hydrodynamic lift force and to the hydrodynamic lift force of its flap 7.

The flap 7 is substantially of the same span as its aileron 1, but has a lesser chord, for example three to four times shorter. The deflection of the flap is ensured by a servo-mechanism of angular orientation (not shown) of the flap 7 with respect to its aileron 1. The deflection angle of the trailing edge flap 7 with respect to the orientable aileron 1 is determined by an onboard electronic calculator (of a known type) which pilots the orientation servo-mechanism. This angle between the aileron 1 and its flap 7 generates a hydrodynamic lift force of the trailing edge flap which forces the orientable aileron 1 to orient itself by taking up an incidence with respect to the current, which in turn generates a hydrodynamic lift force of the aileron. The latter is in a near, but opposite direction and is considerably stronger than the lift force of the flap 7 because of the ratio of lift surfaces of the aileron 1 and the flap 7.

When the boat is confronted with high transversal waves and the fairing 6 is uncovered in the troughs of the waves, the hydrodynamic vane effect of the fairing 6 is no longer fully effective. The inertial effect to which the fairing is subjected drives it in rotation in its momentum resulting in uncontrolled rotational oscillations. And when the following wave covers up the fairing 6 once again, the fairing may well be in a position transversal to the local displacement of the water. This would result in a parasitic transversal lift, the maintenance of forced oscillations of the fairing, and above all an increase in the hydrodynamic drag which would hamper

the boat's speed and/or increase its fuel consumption. So as to avoid such effects, return means 9, of the elastic or motor means type, may be provided between the submersible strut 5 and the rotating streamlined fairing 6 so as to impose an angular restoring force on the fairing when this is angularly offset with respect to the axis of symmetry of the boat. Such return means are widely known. By way of example, a torsion spring or progressive torque servo motor may be mentioned. The aforementioned motor may also be piloted according to the measurement of the angle between the water flow and the fairing 6 so as to align the fairing with the current. Means for such measurement are already widely known. By way of example, a set of submerged pressure sensors arranged on the fairing and cooperating with a calculator or else an angular sensor of a known type measuring the orientation of a submerged vane revolving around a vertical hinge pin integral with the fairing may be cited.

Figure 2 shows another embodiment of a hydrodynamic stabiliser 15 according to the invention. In this embodiment, the submersible strut 5 is still in a vertical plane but is inclined with respect to the vertical z and the fairing 6 is integral with the submersible strut 5. The submersible strut 5 is linked to the boat by a rotating head 29 which revolves freely around the vertical axis z. End guard plates 13 for the ailerons 1, perpendicular to the hinge pin 10, increase the hydrodynamic lift coefficient of the aileron and facilitate the spontaneous orientation of the submersible strut 5, which rotates like a vane in the current, forming transversal foils.

Figure 3 shows another variant embodiment of a hydrodynamic stabiliser 15 according to the invention. In this other embodiment of the invention, the resultant hydrodynamic lift force can be oriented in two directions. The vertical component (upwards or downwards) of this global lift is supplied by the first orientable aileron 1 with horizontal rotational axis around the shaft 3 integral with the lower end of the submersible strut 5. This submersible strut 5 also carries, and in a second upper part, a second

orientable aileron 2 freely rotating around said submersible strut 5 and supplying the horizontal component (towards port or starboard) of the aforementioned global lift. The horizontal 1 and vertical 2 ailerons also comprise trailing edge flaps, respectively 7 and 8, hinged in rotation around a hinge pin close to the trailing edge, respectively 21 and 22, of ailerons 1 and 2. Each flap is controlled by a servomechanism of rotational drive with respect to its aileron so as to orient the aileron according to the mode of operation described previously.

The hydrodynamic stabiliser according to the invention may also be made without trailing edge flaps 7 and 8 but wherein the orientation of the aileron or ailerons 1 and 2 is carried out by motor means (for example an electric motor positioned between the aileron and its hinge pin). Such an arrangement, however, does not enable piloting of the ailerons to be performed as reliably, simply and efficiently as in the embodiment previously described which has flaps.

Indeed, in a first simple variant having no trailing edge flaps, the calculator sends an orientation angle by way of a setting to the orientation means of ailerons 1 and 2, with respect to their mean position, proportional to the lift force required to stabilise the boat; the drawback to this method being that the angle of incidence of the aileron with respect to the current fluctuates according to the transversal speed of the water due to the waves, and thus that the actual hydrodynamic lift force of the aileron also fluctuates around the setting value, hence less efficient stabilisation than previously. In a second variant also without trailing edge flaps, the calculator sends an orientation angle by way of a setting to the orientation means of ailerons 1 and 2, with respect to their mean position, proportional to the angle of orientation required for the angle of incidence of the aileron with respect to the current remains proportional to the lift force required to stabilise the boat (to obtain a constant force, a signal must be sent that fluctuates according to the waves). This second variant without flaps suffers the drawback of requiring means

to measure the water's local flow direction to be connected to the calculator. As explained above, such measurement means of the relative orientation angle of a flow with respect to a solid in movement in a fluid are already widely known (for example based on an angular sensor connected to a submerged hydraulic vane with an axis perpendicular to the axis of the boat or based on submerged distributed pressure sensors).

The orientable ailerons 1, 2 may be fitted with means to improve their lift by suction by means of a pump of the boundary layer through small diameter openings scattered across their surface, these openings being periodically cleared by being briefly flushed out in the opposite direction by means of another pump or by compressed air. According to a variant embodiment, the suction is limited to the suction face of the ailerons and the suction face is switched on when the orientation motor torque direction of the aileron is inverted or when the deflection direction of its trailing edge flap is inverted.

Figures 4a to 4d show embodiment of the rotating fairings 6 according to the invention. With the aim of overcoming the drawbacks linked to the erratic orientation of the rotating fairing in case of high waves, the latter may be equipped with a hydrodynamic lift element 18 acting in addition to or in replacement of the above-mentioned return means 9.

Figure 4a shows a rotating fairing 6 that comprises a hydrodynamic lift element 18 made in the form of a rigid plane plate, integral with the rotating fairing's trailing edge 6 and positioned in a vertical plane of symmetry of said fairing.

Figure 4b shows a rotating fairing 6 comprising a hydrodynamic lift element 18 made by an arm 19 integral with the trailing edge of the rotating fairing 6 and which rigidly carries at its downstream end a rigid plane plate 20, arranged in the vertical plane of symmetry of said fairing.

Figure 4c shows a rotating fairing 6 comprising a hydrodynamic lift element 18 made by two arms 19 and 19' integral with the trailing edge of the rotating fairing 6 and

which carry a streamlined wing 28 rigidly integral or hinged around a vertical axis. In the hinged version, the wing 28 will be oriented with respect to the fairing 6 by means of a servomechanism piloted according to the angle measured between the water flow and the fairing 6, so as to cancel this angle. Means to measure this angle have been described previously with reference to Figure 1.

Figure 4d shows a rotating fairing 6 comprising a hydrodynamic lift element 18 made by an arm 19 integral with the trailing edge of the rotating fairing 6 and which rigidly carries at its downstream end a streamlined wing 23.

These embodiments are given by way of illustration and are in no way restrictive. Other embodiments of hydrodynamic lift element 18 may be envisaged, for example by providing the trailing edge of the streamlined wing 28 with a flap that can be oriented by motor means positioned between said flap and this wing 28.

Figures 5 to 7 show examples of the application of the hydrodynamic stabiliser according to the invention to different types of boats.

Figures 5 and 6 show a boat 24 of the single hull type comprising two substantially horizontal lateral arms 14, fixed to the hull of the boat 24 and each comprising at their end a hydrodynamic stabiliser 15. Each hydrodynamic stabiliser 15 is joined to a carrying arm 14 by means of a lockable pivot link such as will be described later. Locking may be carried out by known means, or by a safety hinge such as described hereafter. The arms 14 are made integral with the boat 24 by a link 49 of the vertical axis pivot hinge type. The boat 24 also comprises one or several static and/or dynamic sensors 25 and a calculator 43 cooperating with the sensor or sensors and piloting the hydrodynamic stabilisers 15. The calculator 43 is, for example, positioned inside the binnacle of the boat and the sensors may be gyroscopes positioned inside the binnacle or else vertical accelerometers fixed at the end of the arms 14 to calculate the instantaneous angle of heel and pressure sensors located on the submersible struts, in the still submerged zones, to

calculate the true mean angle of heel by readjusting the instantaneous heel computation results, as well as a speed sensor to measure the speed of the boat on the water (which is required to know the factor of proportionality between the angle of incidence of the orientable ailerons and their induced hydrodynamic lift force).

The boat's stabilisation device operates as follows:

The electronic calculator 43, to which the motor means for the aforementioned hydrodynamic stabilisers 15 and sensors 25 are linked, forms part, either alone or with one or several other electronic calculators with which it is interconnected, of a navigation system on board the ship.

This system comprises sensors which are all of known types, integral with the structure of the ship, a rotating fairing, or else a hydrodynamic stabiliser, and connected to one or two abovementioned calculators and this system comprises software equipped with a measurement acquisition function from these sensors, such that said sensors and the aforementioned software function cooperate so as to establish numerical values which are periodically updated - for example, 10 to 20 times per second - for the deviation in rotation components of the ship with respect to its nominal trim or heading, which are required to establish the control orders for the orientation actuators of the aforementioned submerged ailerons to the hydrodynamic lift force depending on the movements of the boat and so as to obtain the desired stabilisation effects.

The desired effects, depending on the different embodiments of the device according to the invention, are one or several angular stabilisations (in roll, pitch, yaw or one or several components of these movements).

The calculator 43 determines the necessary stabilising torque for each of the desired angular stabilisations, and then it deduces the required hydrodynamic lift force of each orientable aileron - taking into account its layout with respect to the boat - , and lastly it sends the setting to the orientable aileron's motor means with the aim of obtaining this lift force. It is preferable for this setting

to be the deflection angle of the trailing edge flaps 7 and 8 (Figures 1 to 3) with respect to their orientable ailerons 1 and 2 (taking the speed of the boat into account), said orientable ailerons thereby spontaneously taking up the appropriate incidence at the desired lift force whilst accompanying the wave movement, without the calculator having to take said wave movement into account.

Figure 6 shows the boat 24 equipped with hydrodynamic stabilisers 15 according to the invention, when these stabilisers are in their inactive folded position. The arms 14 have been folded along the sides of the boat and the hydrodynamic stabilisers 15 have been subjected to a rotation of 180° around a horizontal axis parallel to the arm 14, so as to be raised and brought out of the water. Such a configuration advantageously enables the boat to navigate in shallow waters without any risk of damage to the hydrodynamic stabilisers and to reduce the encumbrance of the boat, for example to facilitate its entry and mooring in a port zone.

Figure 7 shows a catamaran whose two floats 27 are fully raised up out of the water on high speed foils, free stabilising in list thanks to the V-shaped inclination of the foils and stabilised in longitudinal trim (nose up or down movements) and in yaw by a hydrodynamic stabiliser 15 according to the invention, with two ailerons 1 and 2 (as shown in Figure 3) fixed at the end of a horizontal arm 14 integral with the stern of the boat, in its vertical plan of symmetry, such stabiliser whose aileron 2 also acts as a rudder to steer the boat.

In another example, not shown, a cruise liner will be provided with six stabilisers 15 according to the invention with a single aileron 1 (as shown in Figures 1 or 2), fixed at the end of six substantially horizontal arms 14. Two lateral arms 14 to port and two other symmetrical arms to starboard fulfil a role that is mainly anti-roll. Another arm 14 straight in front and a last one fully at the rear of the liner fulfil an anti-pitch role. The four lateral arms can be folded in the horizontal plane against the port side and starboard side by means of vertical axis lockable pivot

links. The stern arm and the bow arm can be raised about the deck of the liner by being rotated in the longitudinal vertical plane of symmetry of the ship by means of lockable pivot links with horizontal axes perpendicular to this plane.

Figure 8 show an embodiment of the link between the submersible strut head 5 and the arm 14 by means of a pivot safety hinge with a substantially horizontal axis perpendicular to the boat's plane of symmetry, lockable in the vertical position of the submersible strut 5 by being pressed against an angular limit stop by the magnetic attraction force of magnets. The submersible strut 5 and its rotating fairing 6 are drawn in continuous lines for the vertical position of the submersible strut and in dotted lines to show its semi-raised rearward position. The central horizontal bar 146 of a U-shaped support 141 integral with the arm 14 carries a series of magnets 145 fixed to its upper part. These magnets adhere by magnetic attraction to a plate of ferrous material 144 integral with a lug 143. This lug 143 is itself integral with the submersible strut 5 and rotates freely around a substantially horizontal shaft 142 which is integral with the lateral branches of the U-shape of the support 141. In the event of an excessive rearward load (by hitting an obstacle, for example) exerted on an orientable aileron 1 or 2 (Figures 1 to 3) or on the rotating fairing 6, the submersible strut 5 is thus automatically raised rearwards. This may also be made voluntarily to reduce the draught, for example, by a rearward and upward traction of a rope fixed to the lower part of the trailing edge of the rotating fairing 6.

Such an arrangement advantageously enables the submersible strut 5 to be held in its low position by a resistance locking calibrated for a force tending to push back the submersible strut. This embodiment leaves the submersible strut 5 free to rotate rearwards and thus to be raised when the ultimate stress has been reached.

The hydrodynamic stabiliser according to the invention can also be made without the trailing edge flaps 7 and 8 (Figures 1 to 3) whilst ensuring the orientation of the

aileron or ailerons 1 and 2 by motor means (for example, an electric motor positioned between the aileron and its axis of rotation). But such an embodiment does not enable piloting of the ailerons that is at the same time as reliable, simple and efficient as the embodiment described with reference to Figures 1 to 3.

The preferred embodiment is the one in which the orientable ailerons 1 and 2 are provided with trailing edge flaps, respectively 7 and 8, which procures the double advantage of needing lower power consumption for the orientation and of ensuring better reliability (it is unnecessary for the setting signal to be corrected to avoid a fluctuation of lift due to the waves, which in turn prevents the current direction sensors from being perturbed by algae).

Additionally and preferentially, ailerons of the "compensated" type provided with trailing edge flaps will be used. By "compensated aileron" we mean an aileron whose axis of rotation is located substantially on the profile chord, at around 20% of the length of this chord downstream of the leading edge.

Figure 9 shows an embodiment of the boat according to the invention, here of the sailing boat type, comprising a platform 52, a main fully submerged streamlined float 51 integral with the platform 52 by two supporting pylons 16, four substantially horizontal radiating arms 14 integral with said platform and supporting, at their ends, closed-hull, watertight, streamlined auxiliary floats 53, supporting submersible struts 5 in their lower part extending into the water (such as shown in Figures 1 to 3) and provided with orientable ailerons 1, 2 with hydrodynamic lift effect, a central mast 68 and sails 57 and 59 of classic design, ensuring the propulsion of the boat. In this embodiment of the invention, each sheet 57 or 59 is part of a load compensation device automatically regulating the capsizing torque due to this sail, by cooperating with the calculator 43, and whose structure and operation will be described hereafter.

Each supporting pylon 16 and each submersible strut 5 is encompassed by a mobile hydrodynamic fairing 6 freely rotating under the effect of the local current so as to reduce its hydrodynamic drag as described with reference to Figures 1 to 3 and 4a to 4d. The mobile hydrodynamic fairing concept is already known and therefore does not require further description. Reference may be made, however, to patent FR-2817531 which describes such a fairing. It will, however, be preferable to use a rotating fairing whose restoring torque is increased in the event of misalignment, for example thanks to elastic return means (such as a torsion spring or progressive torque servo motor) and/or thanks to a tail piece with hydrodynamic lift effect located beyond the trailing edge of the fairing's hydrodynamic profile and constituted by a vertical plate integral with the fairing or by a streamlined wing able to move around a vertical axis integral with the fairing and oriented by motor means in cooperation with means to measure the fairing angle with the direction of the local flow of the water. Fairings 6 rotating around supporting pylons 16 of the same type as those described with reference to Figures 4a and 4c may be used for the submersible struts 5 (the pylon 16 in this case acting as the submersible strut 5 with respect to the fairing 6).

The boat also comprises an electronic calculator 43, of a known type, cooperating with means to measure the position, inclination, speed and/or acceleration so as to determine the boat's movements and to model these movements as roll, pitch, and yaw movements as well as alternating movements of the boat's centre of gravity due to the passage of the waves and constituted by the vertical movement of the centre of gravity (alternatively up and down) and by the lateral movement of the centre of gravity (alternatively offsets to port and to starboard). These measurement means may be, for example, height sensors, air sonars 34 by reflection off the water surface, accelerometers 26, submerged pressure sensors, submerged vanes, gyroscopes, or any other means to measure the position, movement or acceleration, so as to determine the boat's movements and to model them as movements of

displacement that are either roll, pitch or yaw movements, and transversal displacement movements of the boat's centre of gravity along two non parallel transversal axes, for example vertical and horizontal.

The calculator 43 also cooperates with means to measure the boat's environment so as to determine the wave movements upstream of each main submerged float 51 (this embodiment only has one of them but a boat may be envisaged according to the invention which has several of them), to model at the float's axis the movements of the water that are transversal to the path of the boat as horizontal movements and vertical movements, subsequently to model the transversal hydrodynamic forces on the main float 51 due to the waves and also to determine the aerodynamic forces on the elements of the boat offering wind resistance. These different means may be, for example, anemovanes, sail orientation sensors, submerged vanes, submerged pressure sensors, air sonars 34 by reflection off the water surface, water surface probes, or else video cameras. When the boat is navigating at a fast rate, with the platform 52 and auxiliary floats 53 entirely out of the water, the calculator 43 cooperates with the orientation means for the submerged orientable ailerons with hydrodynamic lift and with the mobile mass balancing device (described later) so as to maintain the mean level of the water surface substantially at mid-distance from the parts of the boat that must remain out of the water (platform 52 and auxiliary floats 53) and the parts of the boat that must remain submerged (main float 51 and orientable ailerons 1, 2).

The calculator 43 is lastly linked, if need be, to a manual control organ enabling the crew to select the degree of stabilisation of the boat, adjustable by software between the maximum stabilisation (objective 100% stabilisation with respect to short waves and 0% tracking with respect to long waves) and the maximum contouring (0% stabilisation with respect to short waves and objective 100% tracking of the long waves). However, the software keeps full control to ensure as a priority a balance of trim and altitude for the

boat that is enough to limit the probability, when the boat is navigating at speed, with the platform 52 and auxiliary floats 53 fully out of the water, of the platform 52 or an auxiliary float 51 hitting the crest of a wave or of the submerged float 51 or an orientable aileron coming right out of the water in a trough between waves.

The auxiliary floats 53 are spaced around the platform 52 so as to ensure balanced trim when the boat is stopped or moving at low speed. Such an arrangement of the floats illustrates an embodiment of the invention. Other embodiments may, however, be envisaged, for example by making certain auxiliary floats 53 directly integral with the platform 52. In this embodiment, the boat comprises four floats, but the invention may also be built with three floats, or more than three floats.

Figure 10 is a schematic view showing the end of an arm such as that described previously for this embodiment. In this view, the auxiliary float 53 comprises a closed watertight compartment 54 in its central part, and in its front part it comprises acceleration sensors 26, for example linear accelerometers measuring the transversal accelerations both vertical (up/down) and horizontal (port/starboard). The watertight compartment 54 communicates with piping 55 whose operation will be explained later. The auxiliary float 53 comprises a hydrodynamic stabiliser 15 in its lower part, which comprises a submersible strut encompassed by a mobile hydrodynamic fairing 6, freely rotating under the effect of the local current. A sensor 34, of the air sonar type by reflection off the water surface, is fixed to the end of a rod 38 to the front of the auxiliary float. This sensor 34 makes an instantaneous measurement of the vertical distance from the water surface to the front of the boat and cooperates with the calculator 43 (Figure 9) to go around the highest waves when the contouring function is activated by the crew. In this embodiment, the stabiliser 15 extending into the water is fixed directly under the auxiliary float 53, but the invention could well be made by fixing this submersible stabiliser directly onto the radiating arm 14.

The stabiliser 15 implemented will preferentially be a stabiliser such as that described previously with reference to Figure 3. In this embodiment, the hydrodynamic ailerons 1 and 2 have their pivots respectively horizontal and vertical. But the invention could be made using any other type of arrangement with one or several orientable submerged elements with hydrodynamic lift effect, so long as the orientation of the element or elements provides lift whose component in the vertical plane perpendicular to the axis of the constantly submerged streamlined float 51 (Figure 9) is orientable by orientation means controlled by the calculator 43 in any direction of this plane.

Figures 11a and 11b shows the functioning of an adjustable preload device 500 enabling the boat's mass to be increased or decreased. In this embodiment, the platform 52 comprises a tank 17 located near to the boat's centre of gravity and preferably in the lowest part of the boat. This tank 17 is connected to a filling and draining device (for example a pump) enabling it to be more or less filled with water. When the boat is stopped or is navigating at low speed, it is preferable for all the auxiliary floats 53 to be in contact with the water so as to guarantee the boat good stability (Figure 11a). Conversely, at high speeds the platform 52 and floats 53 must be fully out of the water so as to eliminate any hydrostatic or hydrodynamic force exerted on their hull. The preload device 500 enables the height of the boat to be adjusted with respect to the mean surface of the water for navigation at high speeds (Figure 11b). This height must be such that the crests of the waves do not hit the auxiliary floats 53 or the platform 52 and such that the troughs of the waves do not uncover the orientable hydrodynamic ailerons or the main submerged float 51. The operation of the adjustable preload device 500 enabling the boat's mass to be increased or decreased is as follows: when the boat is stopped or moving at low speed, the tank 17 is filled with water so as to ballast the boat. In the fast navigation configuration, the tank 17 is fully or partly drained, depending on the boat load, so that the main float

51 alone ensures the boat's floatability. In this embodiment, the tank 17 is located at the base of the platform 52, but the invention could also be made by placing this tank in the submerged float 51, which is, in fact, preferable in order to lower the centre of gravity.

So as to optimally regulate the boat's preloading, submerged static pressure sensors 40 can be positioned on the submersible struts or on the submerged streamlined float 51 or else air sonars by reflection off the water surface, carried by the floats 53. Piping can be installed to fill and drain the tank 17 by a slot arranged in the fairing 6 rotating around a supporting pylon. More generally, slots in the rotating fairings 6 of the supporting pylons or of the hydrodynamic stabilisers may be used to pass organs linking an emerged zone and a submerged zone of the boat (such as for example: cables, piping, revolving shafts).

Figure 12 shows a constantly adjustable mobile mass balancing device 501. In this embodiment, the boat is seen from the front and it receives the wind from starboard (coming from the left, therefore, in the Figure).

When navigating at high speeds, if a boat were subjected to an angle of inclination α that is too great with respect to the vertical, one or two auxiliary floats 53 on the port side would begin to sink into the water and additionally the two substantially vertical orientable ailerons 2 on the starboard side would begin to emerge from the water and the substantially horizontal ailerons 1 on the starboard side would begin to cavitate and would be on the point of emerging. This would respectively cause a braking effect to port tending to make the boat rotate towards port, then a risk of sudden and total loss of vertical lift of the starboard horizontal orientable ailerons 1 leading to a sudden increase in the list to port and an increased bearing of the port side auxiliary floats 53, thereby accelerating the rotation to port. Similarly, an excessive inclination of the boat either forwards or backwards would cause comparable drawbacks. It is thus essential for a balancing device to be provided enabling the position of the boat's centre of

gravity to be modified, laterally and longitudinally, according to the external loads applied to the boat or to a poor distribution of the payload on board the boat.

The balancing device 501 comprises closed and watertight compartments 54 located in the auxiliary floats 53 and partly filled with water, piping 55 connecting these compartments together and at least one pump 11 and possibly a distributing organ carrying out the distribution of the water between the different compartments. This pump 11 and this distributing organ may be linked to the tank 17 so that tanks 54 are completely filled when the boat is immobile or at slow speeds. The constantly adjustable mobile mass balancing device operates as follows:

The calculator 43 (Figure 9) defines the transfers of water to be made, depending on the mean trim angles of the boat (by trim angles we means the angles of lateral inclination and longitudinal inclination of the boat). The pump 11 and the distributing organ cooperate with the calculator 43 and distribute the water between the tanks 54, by means of piping 55, so as to modify the position of the boat's centre of gravity. The static pressure sensors 40 can be made to cooperate with the calculator 43 in order to detect the trim angles. It is also possible for a constantly adjustable mobile mass balancing device to be envisaged by the lateral and/or longitudinal displacements of mobile counterweights along guides, positioned along these guides by mechanisms comprising actuators and position sensors. However, balancing by the transfer of masses of water remains the preferred embodiment.

Figure 13 is a schematic view showing an embodiment of an arm 14. In this embodiment, the arm comprises two sections 14a and 14b and the auxiliary float 53 is fixed to the radiating arm 14 by a link with several lockable positions. The two sections 14a and 14b are linked together by a link 12 of the horizontal axis lockable pivot type. The link between the float 53 and the arm 14 is, for example, made by a slide carried by the two arm sections and locking means at each of

the two positions, for example a claw and set screw or a conical bolt lock.

In the normal navigation configuration of the boat, the arm 14 is fully deployed and the link between the two sections is locked so that they are not able to rotate with respect to one another. The float 53 is fixed near to the end of the arm 14, near to the submersible strut 5. When the crew wishes to reduce the horizontal encumberment of the boat at slow speeds, for example to facilitate access to the harbour, the arms 14 may be folded. To take up this folded position, the crew unlocks the float 53 then brings it closer to the platform 52 up to the end of section 14a integral with the platform 52 and locks the float 53 in this new position (shown in dotted lines in the Figure). The float 53 being locked in this position, the link 12 between the two sections of the arm 14 is unlocked and the second section 14b is folded over the first section 14a as shown in dots and dashes in the Figure. So as to facilitate this manoeuvre, a cable 47 may be positioned between the end of the arm 14 and a pulley located at the top of the mast 68. A variant embodiment consists in fixing the auxiliary floats 53 to the radiating arms 14 by pivot type links with substantially vertical axis with several lockable positions. This variant embodiment is particularly well adapted when the arms 14 are fixed to the platform 52 by a vertical pivot type link with several lockable positions, such as that described with reference to Figures 5 and 6, to be foldable.

The following paragraphs related to the boat according to the invention describe additional embodiments that may be made of said boat.

In this embodiment of the boat according to the invention, the hydrodynamic stabilisers 15 are of the type shown in Figure 3. Other embodiments of the invention may also be envisaged, for example by making the separate submersible struts 5 carry substantially horizontal 1 and vertical 2 orientable ailerons. Several hydrodynamic stabilisers 15 may also be positioned (of the raisable type, as described later) per radiating arm 14, which enables the

surface of the submerged ailerons to be adapted to the sailing conditions encountered. The two ailerons 1 and 2 of a same stabiliser 15 may also be replaced by a single streamlined submerged element orientable along two axes orthogonal to the axis of the submerged float 51, which element, seen from upstream, looks like two ailerons formed into a cross, or else looks like a rectangular-section nozzle constituted by four ailerons joined together and parallel two by two or a ring-section nozzle (streamlined aileron curved over 360°). However, the embodiment shown in Figure 3 with two independent ailerons 1 and 2 is the preferred one.

The example described above is a sailboat, but the boat according to the invention may also be engine-propelled, for example using onboard fuel. In case of propulsion by submerged propeller(s), it will be advantageous to place the propeller(s) at the rear point of the (or of each) submerged float 51.

To facilitate access into harbours, the main submerged float 51 may be able to be raised up against the platform 52 through the retraction of the supporting pylons 16 with their rotating fairing 6 into housings in said platform, and may even be partly embeddable in said platform thanks to vault accommodation arranged in its lower zone (detail not illustrated).

To increase the boat's speed, the main submerged float 51 may be provided with drag reduction means by suction by means of a pump of the boundary layer through small diameter openings scattered across its surface, these openings being periodically cleared by being briefly flushed out in the opposite direction or by means of another pump or by compressed air.

For a boat of large size, an access from the platform to the compartment of the main submerged float 51 may be provided for maintenance visits or for goods or freight to be stored. This could be a permanent access by a passage via a supporting pylon 16, which is tubular in this case, or a temporary access when the boat is immobile by means of a vertical tube sliding by motor means and made watertight in

the platform 52 so that this tube forms a temporary communication well between the platform and the submerged float 51, in this case, the lower end of this tube being provided with peripheral sealing means (for example, a seal or a ring-shaped suction cup linked to a suction pump) fits tightly against the top of the submerged float 51, around a watertight door arranged in the wall of this float; a pump enabling the water to be evacuated from the tube before the door is opened; when navigating, this tube remains retracted in the platform 52 behind a door.

So as to guarantee good stability for the boat according to the invention when it is of the wind propelled type and so as to optimise the use of the wind as a motor element, it is important to be able to constantly adjust the orientation of the boat's sails. The invention thus also relates to a load compensating device to orient a boat's sail. Such a device can be adapted to and used by any type of sail boat, as well as on other sail craft, for example a sand yacht. The purpose of the load compensation device according to the invention is to exert a variable torque (or a load) on the sail orientation organ, so as to enable either an automatic orientation of said sail according to the wind, or assistance at a defined orientation. By "sail" we mean any organ using the wind force as a motor means applied to the boat, this organ may, for example, be a sail, a wing mast or a Turbosail. By "sail orientation organ", we means the organ integral with the sail and by which the orientation angle with respect to the boat of said sail may be fixed, that is to say, for example, a sheet fixed to one end of the sail or near to the boom integral with the sail, or a connecting rod whose end is integral with the sail or a crank integral in rotation with said sail (for example integral with the base of a rotating wing mast or with the boom of a sail), or else a toothed wheel meshing with an endless screw or a chain or else a synchronous belt, wheel coaxial to the axis of rotation of the sail and integral in rotation with said sail (for example integral with the base of a rotating wing mast or with the boom of a sail).

In the embodiment of the load compensation devices of the example given hereafter, sheets act as the sail orientation organ and each sail is a sail either with or without a boom.

Figure 14a shows the load compensation devices 502 in the orientation of the sails of a boat according to the invention applied to a pleasure sailboat. In this embodiment, the boat comprises a rear sail constituted by a main sail 57 provided with a boom oriented by the mainsheet 56 and a front sail constituted by a jib sail 59 oriented by the sheet 58 located to the leeward side. A central mast 68 supports the main sail 57, the boom and the head of the jib sail 59. The deck 61 is provided with three sheet attachment points: one for the main sail, located to the rear and two for the jib sail, one of which is to the port side and the other to the starboard side. At each of these attachment points, the usual winch is replaced by a device 60 according to the invention to adjust the sheet orienting its associated sail.

Figure 14b schematically shows an embodiment of a load compensation device 502 according to the invention, comprising a global elastic device 201 whose mobile output organ 71 - shown here by a spreader 103 or a cable 71 - drives the orientation of the sail by means of a movement transmission device 200. Said movement transmission device 200 orients the sail by means of the sheet 56 (or 58) which here acts as the sail orientation organ, such as defined previously. In the remainder of the description, "sheet traction device" 60 refers to all the elements constituting the device 502, with the exception of said sheet 56 (or 58).

This sheet traction device 60, in the embodiment envisaged in this example, comprises two joined winches 66 and 69 with opposing winding directions, the second of which 69 comprises a groove 70 having a variable winding radius and by a cable 71 pulling a global elastic device 201, schematised by a spreader 103 attached to tensile springs 37 anchored to the structure 30 of the boat. This global elastic device 201 is shown by way of example. However, a global elastic device 201 is preferred which comprises one or

several elastic organs, each made by a jack connected by piping to a gas tank as will be described later with reference to Figures 15 and 16.

In the embodiment envisaged (Figure 14a), the sailboat comprises three load compensation devices 502 according to the invention, which may be fully separated, or else share the same electronic calculator, located, for example, in the binnacle. Sensors or servo elements may also be common and shared by the three devices 502 (for example: common anemovane, common air compressor used alternately, or else used simultaneously). Within the scope of application of this device to a boat such as described previously with reference to Figures 5, 7 and 9 to 12, the different sensors and measurement means already present on the boat, such as the calculator 43 (Figure 9) already implemented to stabilise the boat, may judiciously be used.

During the design of the device 60, the elasticity properties of the global elastic device 201 and the transmission ratio evolution law of device 200 linked to the evolution of the winding radius on the drum 69 according to the winding angle are selected so as to enable, for a given setting of said properties of elasticity, the moment of the restoring force exerted by the sheet on the sail to be constant, or gradually and slightly rising, when the sail rotates from the orientation corresponding to the "close-hauled" point of sailing to the "following wind" point of sailing. Thus, the tensioning devices 60 for the sheets guarantee that the capsizing torque due to the sails in the event of sudden gusts is not able to increase dangerously (the sail tending to spontaneously orient itself in the axis of the wind). In Figure 14a, the mast 68 is not guyed and is able to rotate 360° around a vertical axis. Vertical stanchions 63, acting as spacers for sheets 56 and 58 from the axis of the boat, located symmetrically to the port and starboard sides, are integral with the deck and each provided with a cylindrical sleeve with protection flanges, revolving on bearings. These stanchions 63 are of a height and arrangement such that the sheets 56 and 58, intercepted mid-

way, press on them when the main sail 57 or the jib sail 59 revolve far forwards, such that the more favourable angle of traction reduces the maximum traction. The jib sheet on the windward side (not shown) is not tensed and is wound around the drum 66 (Figure 14b) of device 60 whose elastic organs are all placed out of commission. Only the eye of the sheet protrudes from the opening in the deck 61, which will receive the hank of the jib sail clew at the next tacking.

In the embodiment envisaged by this example, each of the sheet tensioning devices 60 comprise a cylindrical drum 66, shown more fully in Figure 17, protected by two end plates 67, free to rotate around two conical roller bearings 104 held by a support (not shown) integral with the deck 61, drum 66 around which the sheet 56 or 58 is wound. This drum 66 is integral with a coaxial drum 69 with variable winding radius provided with a groove 70 with multi-turn cam profile, in the hollow of which a flexible and inextensible cable is wound in the opposing direction. The latter supplies an antagonistic torque to that of the sheet by anchoring to a traction clamp 90 integral with the piston rod of a pneumatic jack 72 (Figures 15 and 16), with quasi-zero friction and whose body 73 is integral with the deck 61 by supports (not shown). This jack 72 is linked by piping 81 to a compressed air tank 82, shown in Figure 15. The crew (or a calculator) adapts the mean pressure in this tank according to the wind force and surface of the sail in commission by means of an assembly comprising a compressor, piping, valves and manometer linked to this tank. Regulating the mean pressure in the tank thereby enables the mean jack elastic load to be adjusted.

The evolution of the ratio of the winding radii of the sheet 56 or 58 on drum 66 and of the antagonistic cable 71 on drum 69 according to the angle of rotation of said drums is provided such that the moment of the traction force on the sheet with respect to the axis of rotation of the sail increases substantially linearly according to the angle to the mean plane of this sail with the plane of symmetry of the boat, with a total variation of approximately 10% when this angle moves from 0° (boat "head to the wind") to 180° (boat

"rear wind", sail completely to the front). The invention can also be made differently, for example by also giving drum 66 a variable winding radius, or else by separating drums 66 and 69 and linking them by a gear train, or even by cascading several devices 66, 69 with antagonistic winding.

The invention can be made using one or several elastic organs. In the embodiment envisaged for this example, each elastic organ of the global elastic device 201 is made by a pneumatic jack 72 with quasi-zero friction (Figures 15 and 16) substantially collinear to the traction force of the cable 71. This jack 72 is formed by a cylindrical body 73 inside which a cylindrical piston 74 slides leaving annular play. A flexible tubular reinforced membrane 75 (see detail in Figure 16), anchored to the perimeter of the bottom of the body 73 and to the head of the piston 74, is turned inside out like the finger of a glove and rolls between walls 73, 74 sliding with respect to one another to ensure tightness. The first anchorage is ensured by pinching the membrane between the plate 77 forming the bottom of the jack body and the end flange 76 by means of a screw rim 78. The second anchorage is ensured by pinching the membrane 75 between the piston head 74 and the counter-plate 79 by a screw rim 80. Each anchorage is reinforced (detail not shown) by ribbing at the edge of the membrane, caught between two circular grooves arranged in the faces opposite the plates and counter-plates tightened by screws. The body of the jack 73 is joined to the boat structure and its bottom 77 comprises the opening of piping 81 linking the compressed air tank 82, which is provided with a manometer 83. The pressure in this tank can be regulated, firstly by means of the compressor 84 which lets in air from the exterior and lets it out via the piping 85 which is fitted with a stop valve 86 and secondly by means of a decompression valves 87 which lets air escape to the exterior. The jack's piston 74 is integral, by means of a clamp 88, to two traction rods 89 each guided by two linear bearings (not shown), whose external rings are integral with the structure of the boat. A second clamp 90, integral with the rods 89 at their other end, transmits their traction load

by an eye lug 92 then a connecting shackle 93 which is anchored either directly to cable 71 by a thimble 94 as seen in Figure 16, or (not shown) to the eye of a tackle block of tackle forming a stroke multiplier, whose other tackle block is immobile and integral with the structure of the boat; the end of cable 71 opposed to the winding on the drum 69 is in this case anchored to the structure of the boat and the central part of said cable 71 is tensed between the pulleys of the tackle blocks.

To reach the core of the sheet tensioning device 60 mechanism located under the deck 61, the sheet 56 or 58 passes through the deck (Figure 14b) by an opening through which it is guided by an upper pulley 64, with a rotating horizontal axis mounted on a vertical pivot fixed to the deck, and by a pulley 65 with a horizontal axis whose tackle block is fixed under the deck 61. An auxiliary mechanism (Figure 17) additionally ensures the lateral guidance of the sheet 56 or 58 near to its winding around the cylindrical drum 66.

A second winding guidance mechanism analogous to the previous one is provided (but not shown) for cable 71, arranged symmetrically to the first with respect to the plane perpendicular to the plane of the drawing and passing through the axes of drums 66 and 69.

In Figure 17 each of these two winding guidance mechanisms comprises a pair of pulleys with semi-circular sectioned grooves 95, which are tangent and together form a circular opening delimited by the grooves opposite and by which form a passage for the sheet or cable to be guided. The pivots of these two pulleys are carried by a carriage 96 able to translate in parallel to the axis of drums 66 and 69. This carriage is guided in translation by guidance organs along a rail 97 integral with the structure of the boat. This carriage is made integral by a shoe 98 tightened by screws 99 of a cable 100 stretched in parallel to its path and returned by pulleys 101 with axes perpendicular to the plane of the Figure and integral with the structure of the boat towards two small diameter drums 102, coaxial to the main drums and

integral with them in rotation, onto which the ends of the cable 100 are anchored and wound in opposite directions. In this way, the translation of the carriage 96 is proportional to the angle of rotation of drums 66 and 69. In a variant embodiment, the carriage 96 is driven by a screw-nut system whose revolving element is driven in rotation by the rotation of drums by known, constant ratio, transmission means.

The setting of the unwound length of the sheet at a precise value is piloted by the software of the electronic calculator common to the sheet tensioning devices 60. To this end, firstly the angle of rotation of drum 66 is measured by an angular measurement sensor of a known type, and secondly, a stepper motor of a common type with known pull-out torque has its output shaft integral with the drum by means of a reversible geared rotation transmission mechanism. The angular sensor and the motor's electronic control device are linked to the aforementioned electronic calculator. This sheet regulating device enables the friction to be compensated, whilst allowing the sheet to run in case of abnormal load due to a gusting wind, without losing track of the drum angle, such that an optimal setting may thus be automatically re-established afterwards. The slight angular locking due to the remanent torque of the stepper motor makes constant replenishment of power unnecessary; this slight locking may, if required, be reinforced by a rotary plate ring indexed by spring ball-fitted pawls (every 10°, for example), locked onto the drive shaft.

In the embodiment described previously of the global elastic device, the regulation of the mean elastic load is carried out by modifying the mean pressure in the tank by means of valves. In place of or in addition to this (recommended), it is possible to regulate the mean elastic load by providing several elastic organs and by varying the number of elastic organs in commission at a given time. One means to put an elastic organ out of commission is the temporary elimination of the elastic effect (for example, for jacks, by bringing their chambers to atmospheric pressure using valves). Another means consists in temporarily

uncoupling the base or frame of the elastic organ with respect to the boat structure (which can be performed by a removable link of the mechanical or hydraulic type with a coupling jack). Yet another means consists in temporarily uncoupling the mobile output organ of the elastic organ with respect to the movement transmission device 200 (Figure 14b) (Which could be obtained, for example, by means of a cable hoist, tightened when in commission and slackened when put out of commission).

With reference to Figures 14a to 17, so as to prevent the aerodynamic lift force of sails 57, 59 from reaching the threshold limit below which it suddenly collapses (the angle of incidence of said sail with respect to the wind approaching zero), a calculator cooperating with means to measure the tension in the sheet 56, 58 (for example, the pressure sensor 83 in the tank 82 and a sensor of a known type to measure the angular position of the drum 66) cooperating with the means to regulate the mean load of the load compensator of said sail (for example electrovalves on piping 81 of each of the jacks 72 and electrovalves to vent the chambers of these jacks), so as to maintain the lift force of said sail between two limits depending on the setting of the mean load (in these examples: number and characteristics of the jacks used) would be provided.

The device according to the invention may be used on any type of sailboat or sail craft (for example, sand yacht). It may also be installed on any type of existing sailboat with enough space below deck to hold the different organs of the device, if necessary by slightly adapting the interior accommodation. Moreover, it is particularly well adapted to boats with stabilisation devices such as described previously.

With respect to known means of wind element orientation, the device according to the invention procures the following advantages: it provides improved comfort for the passengers (list being reduced). It improves safety (reduced risk of capsizing) and no longer requires the constant surveillance of the orientation in competitions. Muscular effort is much

reduced in the assistance mode and the consumption of energy is lower than if the device comprised an actuator. The fine tuning of the wind-originating capsizing torque in the automatic mode is particularly advantageous for unstable sailboats, such as those carried by foils or submerged floats.

The embodiment of a load compensation device for the orientation of a boat sail implementing a sail sheet has been given by way of illustration. A compensation device according to the invention can also be obtained by other embodiments. Another possible embodiment consists in linking the variable winding radius drum in rotation, directly or by means of gearing, to the mast 68 supporting the sail or to the sail boom. Other embodiments of the elastic element(s) according to the invention are also possible, which, instead of using the elasticity of a gas in a jack, uses the elasticity of a pressurised gas in a pneumatic accumulator containing a hydraulic liquid in the lower part and whose floor comprises the opening of piping opening out into the chamber of a hydraulic jack, or which uses the elastic deformation of the material of a spring, or else the magnetic force of magnetised elements.

The electric motor actuator aforementioned in the regulation of the orientation of the sail can be advantageously replaced by an automatic pilot for sailboats, of a known type, with a submerged pendular blade mounted loose in rotation around its longitudinal axis and with an orientable trailing edge flap. This automatic pilot can be adapted in the following manner: the deflection angle of the trailing edge flap of the pendular blade will be controlled by a servo motor piloted by a calculator and the two output tiller ropes will be wound, tightened and provided with an anti-slip device, onto a drum mounted free to rotate around a fixed axis with respect to the boat. This drum forms a receiving winch for the pendular movement of the blade when it is displaced transversally to the current when the flap is deflected. Said drum drives drums 66 and 70 in rotation by means of a rotation transmission mechanism with multiplying

gears, of a known type. Another solution may consist in driving said drum by a rotational movement transmission mechanism of a submerged variable pitch, reversible, screw, whose blades will be oriented by a servomechanism controlled by the aforementioned calculator, rather than by the tiller ropes of the automatic pilot.

The load compensation device according to the invention may also be advantageously applied to a sail having two sheets acting symmetrically by installing in common the global elastic device 201 (Figures 14b and 15) and the sail orientation regulation actuator between the two symmetrical devices 60 (Figure 14a) used to retain both the starboard and port sheets. A recommended solution (on the basis of Figure 17) consists in placing two drums 66 relative to the port sheet and the starboard sheet coaxially to drum 69 and in positioning two clutch devices, for example jaw clutches, between drum 69 and the two drums 66 so as to make either the first drum 66, or the second one integral in rotation with drum 69; the actuator, also in common, will be coupled in rotation to drum 69 by a rotation transmission mechanism of a known type.